Successful Maintenance of Green Infrastructure for Stormwater Management: New York City's Staten Island Bluebelt

Une maintenance satisfaisante des infrastructures écologiques de gestion des eaux pluviales : l'expérience de Staten Island Bluebelt, à New York City

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RÉSUMÉ

La ceinture bleue de Staten Island (Staten Island Bluebelt) est une solution innovante et unique aux problèmes de gestion des eaux de pluie et de préservation de l'habitat des zones humides dans un environnement urbain. La Ceinture bleue est située sur plus de 200 ha de couloirs de drainage naturel sur Staten Island. La ceinture bleue est composée de 50 MPG menées à bien, avec plus de 40 MPG dans la phase de planification et de conception. Le succès de ce système de MPG à grande échelle dépend de la mise en oeuvre d'un programme de maintenance réussi. En conséquence, un robuste programme de maintenance a été développé pour le programme Bluebelt. Ce programme de maintenance volontariste comprend les éléments suivants : prise en compte de la maintenance dans la conception, plan de maintenance à court terme et à long terme, éducation et l'implication des populations. Chacun de ces composants est la clef du succès de ce plan de maintenance, qui par la suite est la clef du succès du programme Bluebelt.

MOTS CLÉS

Meilleures pratiques de gestion, maintenance, eau d'orage

ABSTRACT

The Staten Island Bluebelt is an innovative and unique solution to the problems of stormwater management and wetlands habitat preservation in an urbanized setting. The Bluebelt is located in more than 410 acres of natural drainage corridors in Staten Island. The Bluebelt is comprised of fifty completed BMP, with over 40 more BMPs in planning and design phase. The success of this large scale BMP system is contingent upon the implementation of a successful maintenance program. Therefore, a robust maintenance program was developed for the Bluebelt Program. This thriving maintenance program consists of the follow components: consideration of maintenance in design, short-term and long-term maintenance plan, as well as community education and involvement. Each one of these components is key to the success of the maintenance plan, which in turn is key to the success of the Bluebelt Program.

KEYWORDS

Best Management Practices, Maintenance, Stormwater

1. PROJECT BACKGROUND

The Staten Island Bluebelt, one of the largest watershed-level stormwater Best Management Practices (BMPs) programs in the U.S., employs waterways and wetlands as a natural means of providing stormwater management, flood control, and water quality improvement over a 16,000-acre region of Staten Island, N.Y. By preserving and enhancing the natural ecology of the watershed area, the Bluebelt Program has transformed existing degraded areas into ecological gems, while providing the much-needed drainage infrastructure. Since the construction of the first BMPs by the New York City Department of Environmental Protection (NYCDEP) in 1997, the performance of the Bluebelt System has been exemplary, demonstrating that large-scale “green” stormwater infrastructure can be effectively maintained.

The Bluebelt originated as a solution to a problem facing NYCDEP in South Richmond, Staten Island. The implementation of the all-pipe network called for in the previous drainage plans would have obliterated the last stands of contiguous freshwater wetlands in New York City. To address this, an innovative use of BMPs was developed to connect the storm sewers beneath residential streets with the existing natural waterways, including streams, wetlands and ponds. This combination of green with hard-pipe infrastructure is the hallmark of the multi-disciplinary Bluebelt approach. Where the hard infrastructure of storm sewers discharges to natural waterbodies, the interface is managed with green infrastructure. The BMPs are designed to safely detain, treat and convey stormwater runoff and enhance native habitats, while at the same time providing a significant cost savings and minimizing maintenance requirements for NYCDEP.

The successful implementation of the stormwater component of the drainage plan relies on the effective use of drainage corridors in conjunction with the application of the BMPs. NYCDEP has acquired more than 410 acres of natural drainage corridors to protect these waterways and provide the framework for this system.

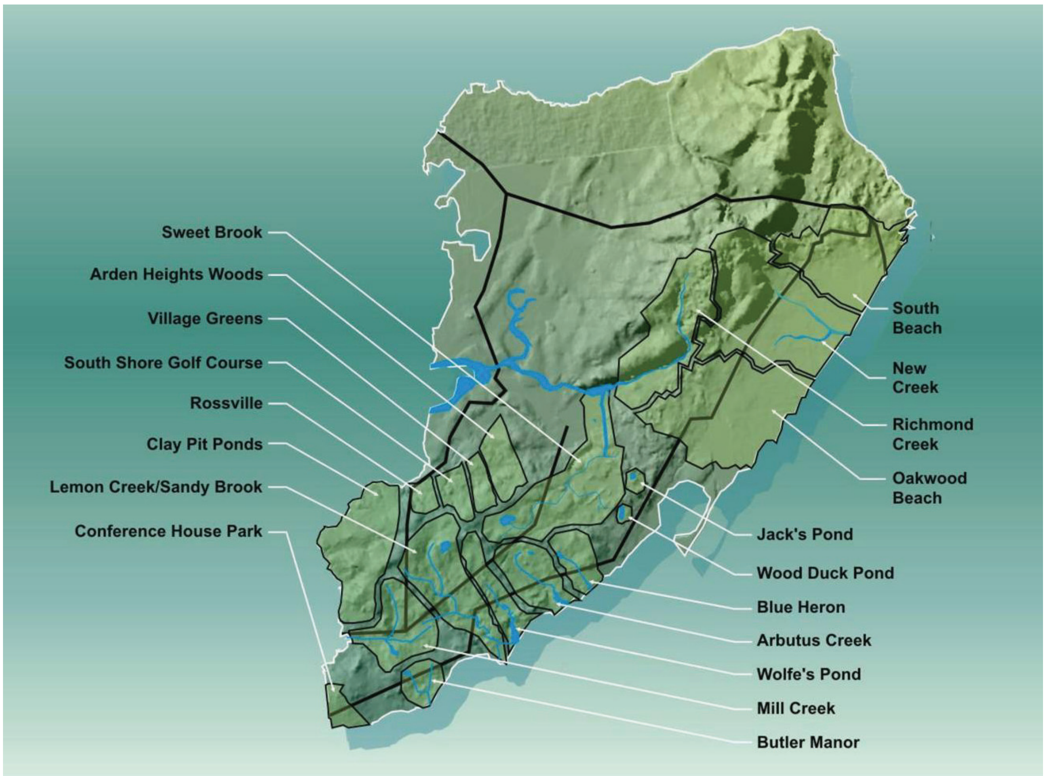

Figure 1: Watersheds of the Staten Island Bluebelt.

The innovative application of BMPs and green infrastructure has become an established stormwater management approach across the nation (Weiss et al. 2007), deriving from the focus on sustainable solutions as well as regulatory impetus. Optimally designed BMPs are cost-effective and easy to implement, providing flood control, improved water quality and aesthetic benefits. However, compared to the conventional pipe-based stormwater facilities, BMPs are much more maintenance-intensive; their performance is dependent on the level of maintenance. If BMP maintenance is neglected, their ability to function as an effective stormwater management system is compromised. Maintenance of the Bluebelt BMPs is performed to achieve four main goals: efficient hydraulic flow and pollutant removal, aesthetic appeal, safety, and mosquito/pest control. The success of the Bluebelt Program is contingent upon the implementation of a successful maintenance program. Therefore, under the Bluebelt Program, a robust maintenance program was developed, containing the following components:

- Consideration of Maintenance in Design
- Short-Term and Long-Term Maintenance Plan
- Community Education and Involvement

2. CONSIDERATION OF MAINTENANCE IN DESIGN

Since 1997, the NYCDEP has implemented and successfully maintained a growing network of BMPs as part of the Staten Island Bluebelt Program. The growing accomplishments of the Bluebelt BMP system are founded on the continuing success of the innovative maintenance plan and procedure. There are now fifty completed BMPs, including twenty-two stormwater wetlands with extended detention, eighteen outlet stilling basins, three pond retrofits, six stream restorations and one sand filter. The maintenance aspect of engineering the Bluebelt BMPs is one of its most unique features, and is considered during the early design phases. Involving maintenance personnel at the beginning of the design phase allowed engineers to ensure that all maintenance concerns were fully evaluated as part of the design, and prior to BMP construction and implementation. One of the benefits of this approach was that BMPs were designed to facilitate maintenance in accordance with the latest research and scientific findings. For instance, Hunt (1999) and Shutes (1997) demonstrated that the majority of the sediment carried in the stormwater runoff settles in the forebay of a wetland. Forebays are located at the inlets to stormwater wetlands and wet ponds.

Figure 2: Construction of a Bluebelt stormwater wetland, illustrating Reno mattresses being placed at the bottom of the low-flow channel.

They are designed to slow incoming water, dissipating the water’s energy and providing a location for sediment and other gross solids (such as leaves, other tree debris and trash) to settle and accumulate. To address this issue, all of the constructed wetlands were designed with forebays and micropools strategically placed for easy maintenance access. Forebay and micropool bottoms were hardened using rip-rap embedded in concrete to facilitate the sediment removal mechanically or by vactoring without scouring. Reno Mattresses are also placed at the bottom of the low-flow channel, so that the design elevations are maintained and sedimentation is easy to remove during vactoring. The hydraulic structures of the BMPs, such as weirs, riser boxes and low-flow orifices, were designed in accessible locations and provided with drain valves or removable weir plates to facilitate the draining of the facility for periodic maintenance.

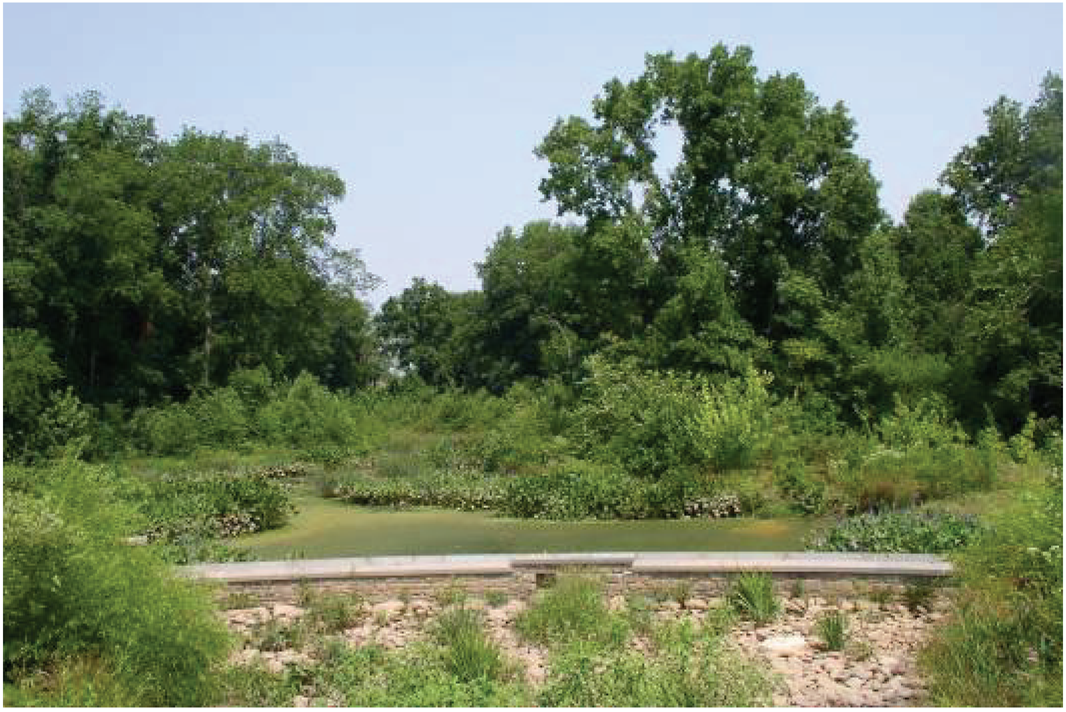

Figure 3: A typical BMP weir designed in an accessible location with removable plates, to facilitate draining of the facility for periodic maintenance at the bottom of the low-flow channel.

3. SHORT-TERM AND LONG-TERM MAINTENANCE PLAN

Once a BMP is on-line, a specific maintenance plan, devised for the BMP in the design phase, is put into action. The Bluebelt engineers individually designed each BMP and respective maintenance plan. To avoid confusion and ensure correct maintenance procedures, the maintenance plan for each BMP is captured on its own maintenance card, specifying the areas of the BMP that require maintenance, as well as the interval and the type of maintenance needed at each specific area. The cards identify the key maintenance items, such as detailed perimeter treatment, precise landscaping requirements, essential structural and hydraulic structures inspection, and required sediment removal (see Figure 9a and 9b after REFERENCE section).

Certain aspects of maintaining BMPs are routine tasks, such as perimeter mowing, pruning, litter pick-up, debris removal and general landscape maintenance. The inspections of the structural aspects of the BMP’s are also done routinely, e.g., weir plates and valves. Other aesthetic, structural and landscaping maintenance includes the perimeters of wooded parcels utilized for stormwater management purposes. These perimeters are maintained and secured as part of the overall field management program. Sediment removal and culvert cleaning is typically not a routine exercise. Observations of sediment loading in the BMPs are made during inspections. When it is determined through physical measurements (i.e. one foot or more of sediment in a forebay) or other obvious visual signs that the BMP and connecting structures need cleaning, cleaning is scheduled and addressed at that time.

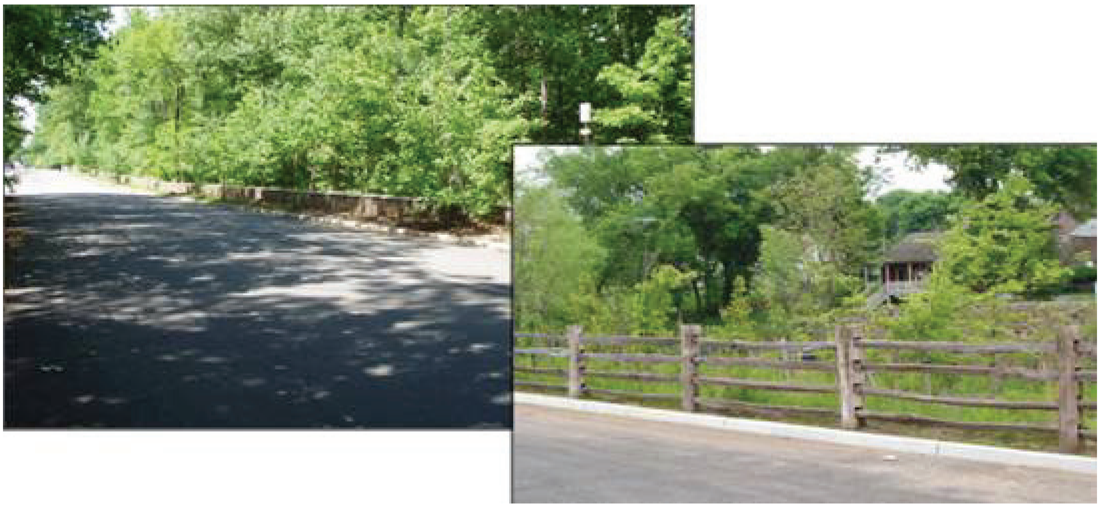

Figure 4: Perimeter treatment secures properties to minimize future dumping.

The principal method employed to clean BMPs such as outlet stilling basins, culverts, forebays and micro-pools, is a vactor truck. The vactor machine is a large, extremely powerful, wet/dry vacuum that is truck mounted and highly mobile. In addition to having the ability to vacuum debris, the vactor also has a high-powered hose spray system that is capable of flushing clogged pipes, cleaning structural chambers and power washing sediment-laden surfaces. Vactor work is highly weather and temperature dependent and is a maintenance procedure used as part of the Bluebelt program to elevate sediment loading in the BMPs. The sequence of vactor work in a BMP typically begins with draw-down of the Water level.. Once the level of water is drawn down, the removal of the sediments captured in the forebay and/or micro-pool Is accomplished using the vactoring procedure as shown in the figure below.

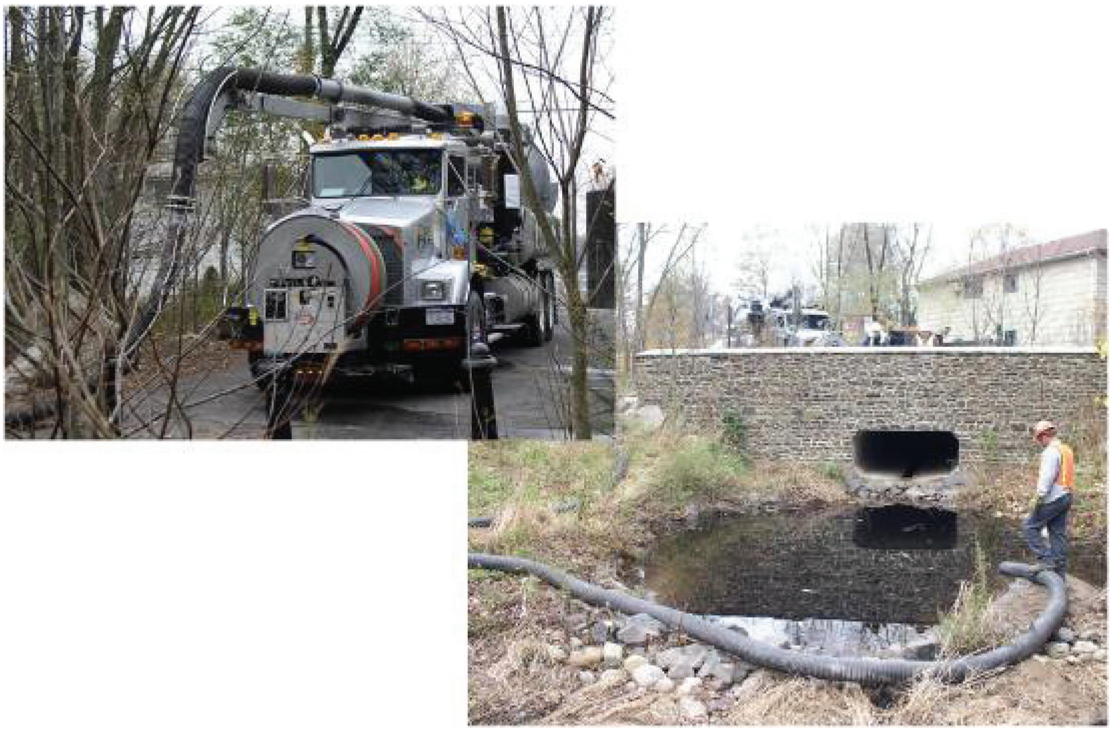

Figure 5: A vactoring crew cleaning out sediment and debris from a typical Bluebelt outlet stilling basin.

The frequency of BMP maintenance for the Staten Island Bluebelt are partly determined by the type, function and geographic location of each BMP. For example, in-stream systems require significantly more sediment removal because of the dynamic nature of urban streams in general. Off-line BMPs, like most outlet stilling basins, require less frequent sediment removal, since less sediment is entering the system. Not only is the function and type of BMP important in determining the frequency of sediment removal from the system, but the geographic location of a BMP is also critical. If the BMP, for example, is located in an area where ongoing construction and development are occurring, then sediment removal intervals will be more frequent due primarily to poor sediment and erosion controls at small construction sites in the tributary watershed. More frequent inspections are also necessary for BMPs located within industrial or commercial areas, or areas with heavy vehicular traffic. These urban land uses generally include significant paved areas that discharge petroleum products, road salt and other pollutants of concern into the BMPs.

Another component of the successful maintenance program is the routine inspection of all the BMPs. Routine inspections of BMPs are critical: they indicate whether or not the BMP is working as designed. If the forebay fills with sediment, these materials will migrate from the forebay and begin to accumulate in other portions of the BMPs that may be more ecologically sensitive. When excess debris accumulates in the BMPs, sediment loads, leaf litter and other organic debris can obstruct the flow paths and cause stormwater backups. In addition, heavy debris loads can accumulate in low-flow orifices and outlet structures.

Maintenance costs, including perimeter mowing, litter pick-up, debris removal and general landscape management tasks, are performed as part of multi-year general expense contracts An other high maintenance cost is vactoring. Vactoring for Bluebelt BMPs are anticipated to require periodic sediment removal once every two years, based on calculated sediment loading. A typical Bluebelt stormwater wetland can be vactored with a three-man crew working five full days to complete all the vactor work costing from $128.00 to $160.00 per cubic yard.

4. ACTIVE COMMUNITY INVOLVEMENT

Another successful aspect of Bluebelt's maintenance plans has been proactive community involvement. NYCDEP works with community groups to organize clean-up days, which both engage the local community and enable the efficient operation of the Bluebelt by removing debris and trash. NYCDEP also organizes tours of the Bluebelt to educate the community, as well as other engineers who want to implement a similar program in their community. In addition, signage at new Bluebelt projects, coupled with the highly successful Adopt-A-Bluebelt program, educate the general public about the benefits of watershed preservation and the environmental consequences of improperly disposing solvents, fertilizers, pesticides and detergents.

Figure 6: The efforts of local volunteers are recognized with Adopt-A-Bluebelt signs.

The Adopt-A-Bluebelt program offers civic-minded companies, organizations, civic groups and individuals an opportunity to enhance Staten Island's open spaces by "adopting," as sponsors, parts of the Bluebelt. Under this program, sponsors may hire private companies -"Maintenance Providers" - to clean areas of the Bluebelt. Each sponsor's generosity is acknowledged with a sign displaying the sponsor's name at the adopted site. To date, over 110 Bluebelt locations have been adopted by individuals, service groups and businesses, saving NYCDEP hundreds of thousands of dollars annually in combined mowing and litter removal maintenance costs.

NYCDEP encourages extensive community involvement, with multiple public forums and a Citizen's Advisory Committee composed of representatives from civic, homeowners, environmental and building associations. Newsletters, signage and a 24-hour hotline for residents to report environmental violations have have contributed to raising public awareness about the advantages of watershed protection, as well as the damaging effects of solvents, fertilizers and detergents on the environment.


Figure 7: Students from a local high school are helping vegetation at a BMP implemented near school grounds.

5. BLUEBELT PERFORMANCE

Proof of the Bluebelt BMPs' maintenance success is the improvement in the water quality of the receiving streams. The measured dry-weather removal efficiencies are as high as 90 percent for fecal coliform and 66 percent for total phosphates, while wet-weather removal efficiencies as high as 38 percent for total organic carbon and 40 percent for nitrates were recorded, for limited sampling done in a few BMPs. The once septic-laden and degraded waterbodies and streams are now healthy, and exhibit high ecological diversity. The United States Environmental Protection Agency, Urban Watershed Management Branch, has conducted long-term monitoring of a Bluebelt retention pond, before and after maintenance (O'Connor and Rossi, 2009). The purpose of the monitoring was to examine the effects of the maintenance on the BMP and the efficiency of pollutant removal. In the study the BMP was found to be exceeding predicted levels of sediment removal, but at the same time discharging excess chemical oxygen demand into the receiving waters. Post maintenance sampling of the BMP, however, indicated a dramatic improvement in COD removal. This was almost certainly due to the removal of excess leaf litter in the BMP and tributary catch basins. The monitoring study provided valuable information to the Bluebelt maintenance program and served as an impetus in modifying maintenance activities and cleaning schedules, particularly for BMPs subject to heavy leaf litter loading and organic debris.

Figure 8: Looking into Porzio's Pond, an extended detention pond, from the maintenance accessway.

The Bluebelt Program makes evident that the successful design and maintenance of stormwater BMPs both ensures flood protection and improves water quality. Successful maintenance can be achieved by considering maintenance issues when designing the BMP, creating maintenance cards, involving and educating the community and evaluating all available tools to successfully handle the maintenance needs. Properly maintaining all the Bluebelt's BMPs allows for the continued success of Staten Island's large-scale green stormwater management system.

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MAINTENANCE PROCEDURES

BMP Site: BH-2
Location: Eylandt Street (Blue Heron Watershed)
Facility: Extended Detention Wetland
Property Ownership: NYC Dept. of Parks & Recreation

DEWATERING PROCEDURE AT FOREBAY & MICROPOOL

The forebay/micropool must be dewatered before proceeding with vactoring operations. A NYSDEC-approved technique must be adopted to isolate the forebay/micropool prior to dewatering.

Methodology:

1) Unlock and open the swing guide rail gate at Location A (see Fig.2).
2) Park at the end of the 15-foot wide maintenance accessway near the forebay (see Location B on Fig.2).
3) Ensure clear access for a two-person crew down the eastern slope near the forebay to location C.
4) Using a NYSDEC-approved technique/tool, such as a sand bag wall, isolate the forebay by erecting the sand bag wall perpendicular to the direction of flow at Location 1.
5) Ensure that the sand bag wall extends up the slope of the extended detention zone beyond the edge of water (see Location C on Fig.2) to ensure no flow conveyance downstream.
6) Pump out the water from the forebay to the wetland downstream.
7) Proceed with vactoring operations (described below).
8) On completion of vactoring work, disassemble the sand bag wall manually and remove from site.
9) Drive the vactor truck west along Eylandt Street to Location E, and unlock and open the swing guide rail gate. Drive along the maintenance accessway and park the truck at Location F near weir.
10) Repeat steps 3-8 at the micropool (see Locations G & 2 on Fig.2). Dewatering the micropool can be expedite by fully opening the knife gate valve of the low-flow orifice.

VACTORING PROCEDURE AT FOREBAY & MICROPOOL

Methodology:

1) Park the vactor truck at the end of the 15-wide maintenance accessway so the boom is extended in the direction of the forebay (see Location B on Fig.2).
2) Connect the vactor truck to an approve nearby source of clean water for vactoring purposes.
3) Unwind the water jet hose reel and place it down the slope of the forebay to Location D. The high velocity water jet hose is used to loosen the accumulated sediment.
4) Extend the boom in the direction of the forebay. Place the 6" *Camflex* suction hose down the slope into the forebay (see Location D on Fig.2).
5) Perform vactoring operations by simultaneously using the suction arm and water jet hose to remove slurry until the base of rip-rap embedded in concrete is reached.
6) Continue slurry removal until the 15 yd^3 capacity of vactor truck is reached.
7) Stop vactoring work. Dispose of slurry at a suitable location off-site; dispose of filtered water to nearby storm sewer.
8) Repeat steps 2-7 until all the sediment has been removed.
9) Drive the vactor truck onto Eylandt Street and proceed west towards the entrance to the other maintenance accessway (see Location E on Fig.2).
10) Unlock and open the swing guide rail gate at Location E, and drive to Location F.
11) Repeat steps 2-7 at micropool (see Location I on Fig.2) until all the sediment has been removed.
12) After vactoring work is complete, carefully remove the 6" *Camflex* suction hose and the water jet hose from micropool, and transport them back to the truck.
13) Inspect the accessway and adjacent area for damage, such as, dislodged field stones, wood chips, etc., and refurbish as required.
14) Disassemble the sand bag wall manually and remove from site.

Note: Make sure the locks on the swing guide rail gates are secure prior to exiting site.

GRAFFITI REMOVAL PROCEDURE

Methodology:

1) Ensure that the surface to be cleaned is free of loose debris.
2) Using a spray tank filled with *Graffiti Free*, an orange-colored graffiti cleaning solution, or approved equivalent, uniformly spray the surface.
3) Wait 5 to 10 minutes.
4) After about 10 minutes, scrub the surface with a thick-bristled nylon brush.
5) Rinse with clean water from an approved nearby source
6) Repeat steps 2-5 if necessary.

Figure 9a: Front of typical Bluebelt maintenance card.

GENERAL MAINTENANCE CARD

BMP Site: BH-2
Location: Eylandt Street (Blue Heron Watershed)
Facility: Extended Detention Wetland
Property Ownership: NYC Dept. of Parks & Recreation

Staten Island BLUEBELT

Major Areas of BMP:
A) Forebay
B) Micropool
C) Weir Wall with Low-Flow Orifice
D) Permanent Pool
E) Extended Detention

SHORT-TERM MEASURES (FREQUENCY: AT LEAST ONCE A MONTH)

Drainage Issues:

1) Inspect Permanent Pool wetland surface area.
   - Remove accumulated debris/floatables by hand or skimmer; use waders if required.
   - Note the existence of excessive algae, if present.
2) Visually inspect the headwall and 68" x 43" elliptical inlet pipe.
   - Remove accumulated debris by hand or skimmer; use waders if required.
   - Repair cracks in pipe using a sealant, if required.
   - Repair cracks, damaged stone on headwall, if required.
3) Inspect the 30-foot weir wall and 12" low-flow pipe with knife gate valve (see Location C on Fig.1).
   - Complete Outlet Structure Inspection Checklist (attached).
   - Repair cracks/damage on weir wall, if present.
   - Correct any issues related to flow short-circuiting, if present.
   - Correct any issues related to knife gate valve functioning if required.
   - Manually remove debris lodged in low-flow pipe; disposed of properly off-site.
   - Replace displaced/damaged outlet protection field stone.
4) Inspect adjacent catch basin grates and manhole covers.
   - Remove accumulated debris; dispose of properly off-site.
   - Secure manhole covers using a hook.

Landscaping Issues:

5) Inspect overall condition of installed vegetation.
   - Remove invasive plants manually if possible, ensuring root removal; dispose of properly off-site. Contact Field Manager for advice if required.
   - Relocate muskrats and/or provide exclusion devices; consult Field Manager if required.
   - Cut grass located along street frontages, as required.
   - Trim shrubs along street frontages, as required.

Perimeter Treatment:

6) Inspect overall condition of the perimeter treatment items
   - Remove accumulated litter/debris by hand; dispose of properly off-site.
   - Promptly notify DEC police regarding illegal dumping issue.
   - Lubricate locks and hinges, as required.
   - Inspect and repair damaged sidewalks, fencing, guiderails, and BMP signs, as required.
   - Refurbish wood chips on accessway, as required.

MODERATE-TERM MEASURES (FREQUENCY: ONCE EVERY SIX MONTHS)

Drainage Issues:

1) Measure the sediment depth in forebay/micropool (see Locations A and B on Fig.1).
2) Inspect for unstable embankments
   - Repair/reinforce unstable embankments using field stone, plantings, etc.

Landscaping Issues:

3) Inspect for septic inflow and nuisance odors.
   - If septic inflow exists, introduce plantings that promote nutrient uptake.
   - Remove dead animals causing foul odor, if present.
4) Inspect plant mortality.
   - Remove dead plants by hand; dispose of properly; replant as required.
   - Trim and remove specified trees, as required.

5) Inspect for herbivore damage.
   - Repair burrows/damage created by muskrats, or other critters.
   - Introduce alternative plantings, if required. Consult Field Manager.

LONG-TERM MEASURES (FREQUENCY: ONCE EVERY TWO YEARS)

Drainage Issues:

1) Vactoring Activity
   - Vactor sediment from forebay/micropool
   - Vactor sediment from adjacent catch basins.

LONG-TERM MEASURES (FREQUENCY: ONCE EVERY TEN YEARS)

Drainage Issues:

1) Vactor accumulated sediment from entire extended detention wetland. Use reno mattress shown on Fig. 1 as a platform for dredging operations.
2) Replant native wetland plants.

Note: Fill out the attached Short-term and Long-term General Inspection Checklists during inspection of the site.

Required Maintenance Permit Checklist:

Issuing Agency	Regulated Parameters
U.S. Army Corps of Engineers	Sediment removal and placement of fill within wetlands
NYS DEC	Temporary dewatering of wetland; revegetation; herbicide application
NYC Parks Department	Tree removal

Figure 9b: Back of typical Bluebelt maintenance card.